Technical Memorandum

Refinement of Conceptual Site Model
Conceptual Site Model/Problem Formulation
Lower Passaic River Restoration Project
March 3, 2006

This memorandum presents updates to the conceptual site model (CSM) presented in the Pathways Analysis Report (PAR) (Battelle, 2005a), which will be incorporated into the baseline ecological risk assessment (BERA) for the Lower Passaic River. Specifically, it provides a more in-depth discussion regarding the sources of chemical contaminants to the river, a refined screening process for the contaminants of potential ecological concern (COPEC), and updates to the list of wildlife receptors as discussed at the project-specific BERA Workshop, held in December 2005 at the USEPA Edison, NJ office.

This memorandum is divided into the following sections:

Section I. Sources of Chemical Contaminants
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I. Sources of Chemical Contaminants

As discussed in the PAR (Battelle, 2005a), the Passaic River has been subjected to expanding urban and industrial development over the past two centuries, which has resulted in a dramatic industrialization of the Passaic River and the Newark Bay watershed. By the early twentieth century, Newark was one of the largest industrial cities in the U.S., with well-established industries such as petroleum refineries, shipping facilities, tanneries, and various other manufacturers. Anthropogenic influence on the natural habitat from this industrialization included the direct release of large amounts of chemicals and human wastes into the Passaic River, as well as habitat destruction, wetlands drainage, and land alteration.

Currently, numerous facilities along the Passaic River serve as point-source discharges to the river, affecting the quality of both surface water and sediment environments. More than 50% of the 120 New Jersey Pollutant Discharge Elimination System (NJPDES) permitted discharges into the Lower Passaic watershed are industrial sources such as asphalt plants; plastic, metal, stone, clay, and glass manufacturers; sawmills; communications equipment facilities; and various public utilities (NJDEP, 2002).

Because of the known historical release of chemicals into the river, historical permitted discharge points are just as important to the CSM as are the active permitted discharge locations. Discharge data were obtained from the NJDEP website as a GIS shapefile entitled NJPDES Surface Water Discharges (updated March, 2005). According to NJDEP, this file consists of both active and historical permits; however, an additional dataset of historical permits that were issued between 1975 and 2001 was obtained from the NJDPES Permittees Database (available at: http://www.state.nj.us/dep/dwq/database.htm). Over 75 different categories of discharge permits were defined in the NJDEP Permittees database. Because specific chemical release information from each permitted facility was not available, data were mapped and analyzed by permit (discharge) type. Figure 1 depicts both the historical and active NJPDES permits under general permitting discharge categories. For this analysis, similar discharge types were combined into a single group. For instance, the seven types of stormwater discharges were combined into one generic category – Stormwater runoff. The end result was the classification of the discharges into 11 general categories: combined sewer overflows (CSOs), *in situ* treatment, industrial discharge, non-contact cooling water, petroleum cleanup, potable water treatment plant, residuals, sanitary discharge, scrap metal processing/auto recycling, site remediation, and stormwater runoff. Any discharge that was considered to have more than one type of permit is symbolized as "multiple categories". A definition of each of the discharge categories is presented below:

- **Combined sewer overflows (CSOs)** are drainage pipes that carry flows from both rainwater and sewers together. During normal conditions the flow is generally delivered to treatment plants. During heavy rains, however, flow amounts sometimes double or even triple, causing the system to become overloaded. CSOs act as relief points by letting excess flows leave the system upstream of sewage treatment plants, into the nearest body of water. This prevents sewage backups into homes and onto area streets. The general CSO permit regulates all portions of CSOs. The permit relies upon the development and implementation of best management practices, technology-based control measures, self-monitoring, and permit compliance certification.

- ***In situ* treatment** is a bioremediation technology for the clean-up of contaminated soil and groundwater. It may consist of oxygen additions, anaerobic substrates, nitrogen, phosphorous, and/or nitrate additions.

- **Industrial discharge** includes industrial spray irrigation, industrial overland flow, industrial surface impoundment, industrial underground injection, thermal and commercial discharge, and industrial subsurface disposal.

- **Non-contact cooling water** is used to cool down various types of industrial and manufacturing equipment without directly coming into contact with facility processes.

- **Petroleum cleanup** includes the discharge of treated groundwater from petroleum leaks (*e.g.*, fuel oil, diesel fuel, kerosene, aviation fuel, and gasoline) into select surface waterbodies. The permit is flexibly designed, addressing several different discharge scenarios. For example, groundwater contaminated by a gasoline spill, which is pumped from the ground and treated prior to discharge to a stream, would be one type of process requiring this permit.

- **Potable water treatment plants** discharge filter backwash and clarifier water to outdoor basins. The discharge results from the process of bringing raw water supplies to drinking quality standards, which often requires the removal of low concentrations of iron, manganese, organic matter, and trace amounts of other metals. When filters are backwashed or when clarifiers are cleaned, the wastewater generated is usually discharged to an outdoor infiltration-percolation basin, which ultimately discharges to groundwater. The general permit requires sampling of accumulated sludge from the infiltration-percolation lagoon, among other requirements.

- **Residuals** are generated by both domestic treatment plants (sewage sludge) and industrial treatment plants (industrial residuals). Residuals are managed in variety of ways, including the development of Marketable Residuals Products (often referred to as biosolids) used to fertilize or condition the soil. Examples include pellets, compost, and alkaline materials. Beneficial use of residuals as a fertilizer or soil conditioner is regulated under a permit and may require site specific approvals, depending upon the nature of the residual. General permits for residuals include regulations pertaining to the land application of food processing by-products, phragmites reed beds, residuals surface impoundment, and residuals storage and transfer sites.

- **Sanitary discharge** includes domestic surface water discharge, community septic systems, sanitary spray irrigation, sanitary overland flow, sanitary surface impoundments, sanitary underground injection, and sanitary subsurface disposal.

- **Scrap metal processing/recycling** includes stormwater from facilities involved in the recycling of materials, including scrap metal yards, battery reclaimers, salvage yards, and automobile junkyards.

- **Site remediation** authorizes the discharge of treated groundwater to surface waters of the State. These permits regulate discharges from remediation cleanups that do not typically contain petroleum products.

- **Stormwater runoff** includess construction activity stormwater, basic industrial stormwater, and individual stormwater permits. Individual permits are issued to facilities that cannot eliminate exposure of pollutants to stormwater. These facilities are required to develop and implement Stormwater Pollution Prevention Plans to minimize or eliminate contact between pollutants and stormwater.

The magnitude of each discharge point is illustrated in Figure 2. Each discharge point is categorized by NJDEP as either minor, which is defined as releasing less than 1 million gallons per day (mg/d); or major, which is defined as releasing greater than 1 mg/d. Any discharge that did not specify the amount of discharge or did not fit into either of these categories is labeled as “other”. The majority of the discharge permits along the Passaic River are classified as minor discharges; 12 major dischargers are located along the Passaic River (Figure 2).

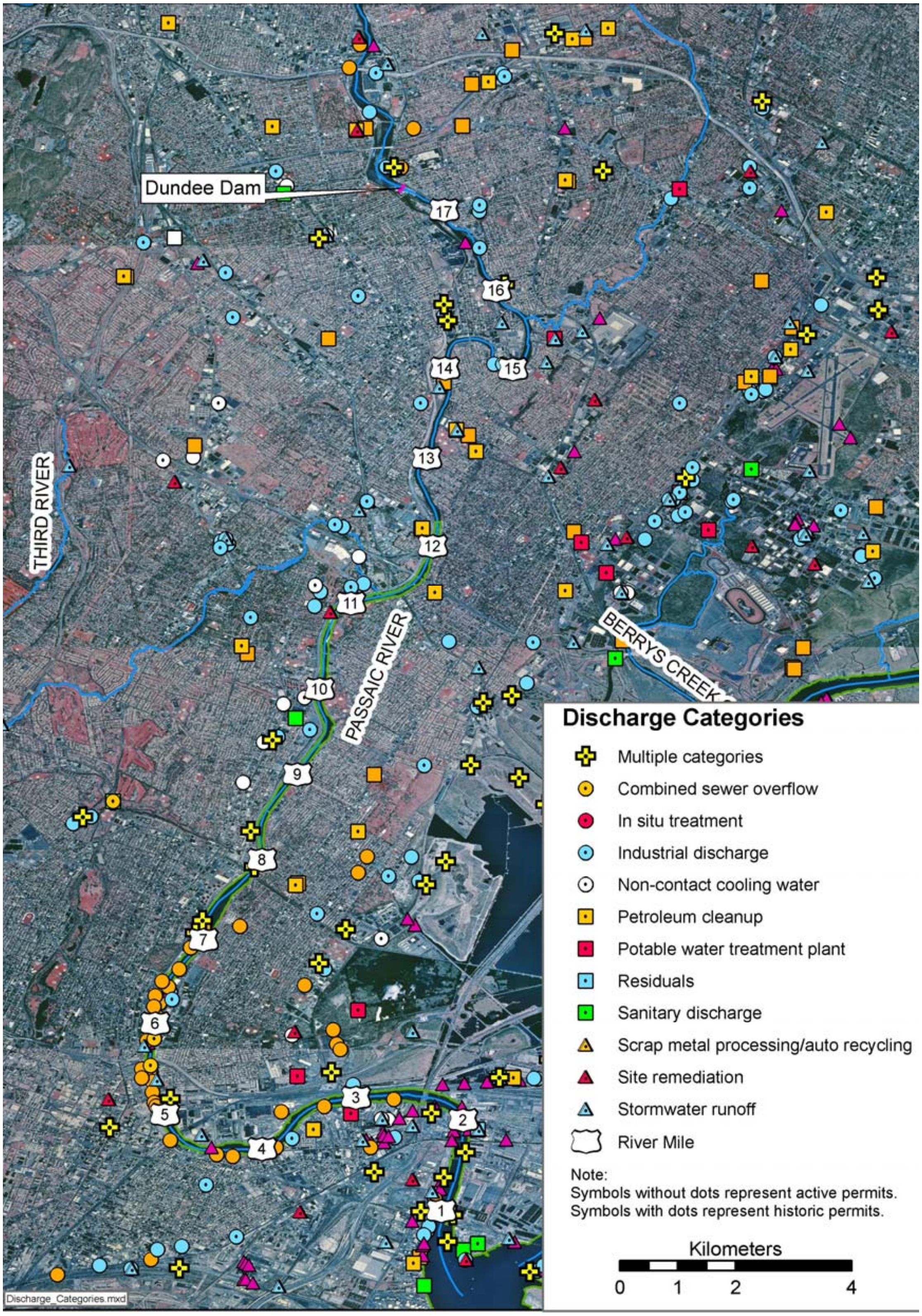

Figure 1. Point-Source Discharges into the Passaic River by NJPDES Discharge Category
(*source: NJDEP*)

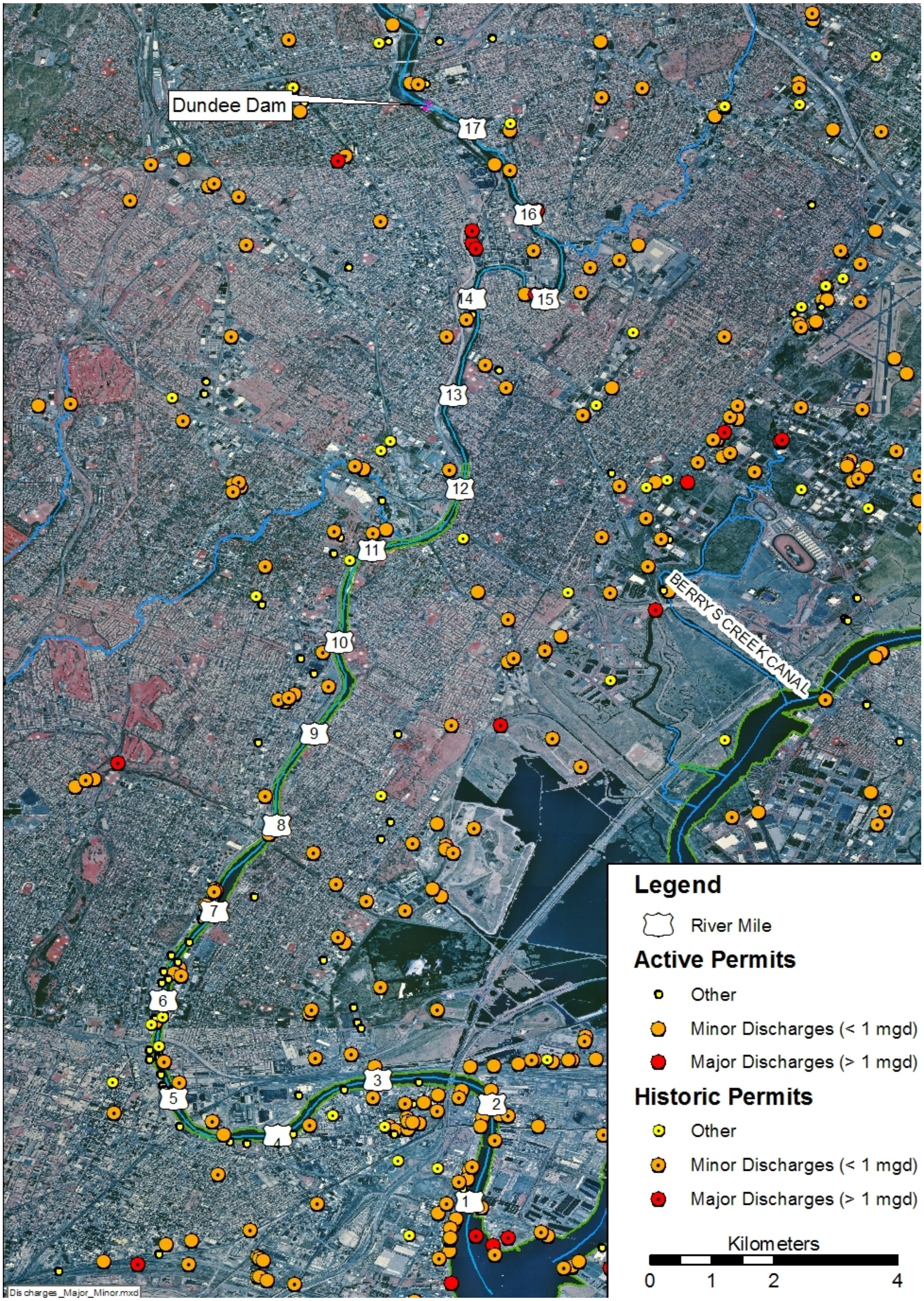

Figure 2. Magnitude of NJPDES Point-source Discharges into the Passaic River
(*source: NJDEP*)

Figure 1 clearly shows that the majority of point-source discharge locations along the Passaic River are south of river mile (RM) 7, which consists mainly of CSOs (orange circles) and sites under remediation (red triangles). Three major sanitary discharge points (green squares) are located at the junction of the river and Newark Bay. In addition, there is one minor sanitary discharge station just before RM 10 (Figures 1 and 2). Various industrial discharges (blue circles) are scattered along the river and along its tributaries, with a cluster of minor ones located at RM 11, where the Third River joins the Passaic. At RM 16 and between RM 14 and 15, there are several major dischargers holding multiple permits (yellow crosses). Various tributaries such as the Third River, Saddle River, and other small streams have several permitted discharges including industrial sources, petroleum cleanup sources (orange squares), and site remediation. Three potable water treatment plants (red squares) were located between RM 3 and 4, along with CSOs, industrial, and petroleum cleanup discharge locations. The majority of non-contact cooling water discharge locations (white circles) are between RM 8 and 12, with a total of six locations.

A thorough understanding of the locations of the point-source discharges into the Passaic River, in combination with further understanding of the sediment transport processes, will enable future sampling activities to focus efforts in specific areas of the river that may impact ecological receptors. The transport of solids and the vertical and horizontal extent of contaminants in the sediments in the Lower Passaic River (RM 1 to RM 7) are summarized in the Draft Geochemical Evaluation (Malcolm Pirnie, 2006). The information presented in Figures 1 and 2 shows a higher number of point sources in the downstream (RM 1-7) portion of the river than in the upstream portion (RM 7-17). This analysis did not include quantifying potential sources above the Dundee Dam that may influence contaminant loading to the sediments. As recognized in the Draft Geochemical Evaluation (Malcolm Pirnie, 2006), there maybe a significant source of contaminants upstream of RM 7 that could be contributing to the contaminant loads to the sediments in the lower portion of the river. For example, there are known petroleum cleanup discharges located between RM 13 and 14, and north of RM 17, which may be a source of hydrocarbon contamination. Exemption (b)(5) - predecisional -deliberative
Exemption (b)(5) - predecisional -deliberative
Exemption (b)(5) - predecisional -deliberative Locations of both historical and currently active industrial discharges, in combination with sediment transport modeling, will provide additional information to assess contaminant loading to the sediments. Further investigations are planned to better distinguish and assess the relative contribution from these various sources and how these sources may influences sediment loads.

In addition, water quality and habitat conditions will be reflective of the quality of the discharge released from various points along the river. For instance, water temperatures may be higher between RM 8-12 because of the non-contact cooling water discharge points along this portion of the river. Non-contact cooling water is heated as it flows through industrial machinery and then is released without coming into contact with chemicals. Water temperature is critical to many organisms' spawning behavior (e.g., fish) and development (e.g., tadpoles), and elevated temperatures may reduce essential habitat for some species. Turbidity and oxygen levels in the water may also be affected, especially near the sanitary discharges, where excessive nutrient discharge could raise biological oxygen demand (BOD) and reduce vital oxygen levels in the water and benthic environments. Additional field surveys will likely be necessary to determine whether these potential stressors are impacting essential habitat at the LPRRP site.

II. Conceptual Site Model and Receptors of Concern

As part of the PAR (Battelle, 2005a), a preliminary CSM was developed for the ecological risk assessment. The purpose of the CSM is to summarize the sources of contaminants, the mechanism of transport, contaminated media, potential routes of exposure, and the likely ecological receptors that may be exposed. It should be noted that the development of the CSM is an iterative process that will continue to be refined as additional information is gathered and analyzed through Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) studies and Water Resources Development Act (WRDA) investigations.

<u>Habitat Evaluation</u>

The increased urbanization of the Passaic River watershed has resulted in extensive habitat loss and degradation of the structural and functional integrity of the ecosystem. As documented previously in the PAR (Battelle, 2005a), over 88% of the wetlands in the Newark Bay area have been eliminated since 1940. The few remaining wetlands are discontinuous, often measuring only a few feet in width (USACE, USEPA, OMR/NJDOT, 2003). In addition, much of the shoreline has been covered by bulkheads, rip-rap, structures, and pavement limiting the areas of critical habitat. As a result of limited wildlife habitat along the river, the focus of field activities to support the BERA will be in the mudflats, wetlands, and remaining riparian habitat.

Updates to the CSM from the PAR focusing on chemical fate, transport, and hydrogeological processes were prepared by Malcolm Pirnie (Malcolm Pirnie, Inc., 2005). To characterize the tidal regime associated with the Passaic River study area, the river was segmented into three salinity sections, 1) freshwater, 2) transitional, and, 3) brackish. These three tidal regimes are important to characterize and predict fate and transport processes throughout the river. The salt water intrusion into the freshwater sections of the river during diurnal tide cycles results in mixing and associated changes in the water chemistry, which can influence the fate and transport of chemical contaminants. However, in examining the biological component of the CSM, there is only a need for two salinity segments, a freshwater and brackish or estuarine segment, because there are no species being considered in this assessment that are strictly limited to the transitional segment of the river. Many of the macroinvertebrate and plant species evaluated have defined salinity tolerances that limit their presence in either the brackish or freshwater segments of the river. These observations are discussed further in the following section to determine the boundary for these two zones. However, many of the other estuarine species can tolerate wider ranges of salinity and can migrate into the transitional area. In fact, several of the receptors, such as the avian species (herring gull) and anadromous fish (*e.g.*, striped bass) are capable of utilizing the entire 17-mile length of the study area. The importance of the transitional zone for the BERA is the recognition that this segment may naturally have low species diversity; this is likely to be most prominent in the benthic invertebrate communities. Due to the diurnal changes in salinity, the transitional segment of the river will only support those species that can physiologically adapt to extreme changes in salinity (0.5 ppt to 18 ppt). This will need to be considered when assessing possible impacts from anthropogenic sources.

To spatially define the likely boundary between the two predominant salinity ranges, results from a geophysical and benthic habitat survey (including sediment profile imaging) of the Lower Passaic River (Aqua Survey, Inc., 2005a, b; Germano & Associates, Inc., 2005) were analyzed. Both surficial and sub-surface geology and benthic habitat structure of the river from the Dundee Dam to its confluence with the Hackensack River were investigated. Together these studies provide the most detailed assessment of conditions at the sediment/water interface currently available for the entire study area.[1] The principal conclusion derived from a preliminary assessment of these data is that the extent of freshwater habitat within the study area may extend farther downstream than expected, and may represent well over 50% of the study area; that is the area from RM 7.5 upstream to the Dundee Dam. This determination is based on the presence of non-estuarine or salt-intolerant macroinvertebrate fauna such as dipteran midge larvae. As with other benthic macrofauna, this non-estuarine (*i.e*., salt-intolerant) taxon is an integrator of environmental exposures and may provide a good estimate of the downriver extent of consistently freshwater conditions. These boundaries can be further refined once adequate salinity data and further planned benthic invertebrate studies are completed and reviewed.

In addition, the data from these studies (Aqua Survey, Inc., 2005a,b; Germano & Associates, Inc., 2005) indicate that the river sediment in the upper and lower reaches of the study area consists predominately of rock/gravel and silt, respectively, whereas substrate in the middle reaches is more variable. Substrate characteristics are obviously one of the primary determinants of the macroinvertebrate community structure. Furthermore, the benthic macroinvertebrate communities in the Lower Passaic River are characterized by their generally low diversity and abundance, as well as degree of spatial heterogeneity. In part, the structural variability is likely a reflection of the identified patterns of relative substrate stability. Although the river bed sediment is comprised predominately of silts, organic rich sediments were also detected during the geologic survey, as well as a range of gravels to fine-graded sands and clays. Sidescan sonar data were used to develop a geological characterization of the bed sediment for the entire study area (Aqua Survey, Inc, 2005a). A simplified surficial riverbed classification map was prepared (Aqua Survey, 2005a) that supports the following conclusions:

- Silt predominates throughout the study area, with varying combinations of silt, sand, and gravel present;
- The riverbed is much more varied above the West Arlington Railroad Bridge (~RM 8), with the channel consisting of sand or silt/sand with silts limited to depositional areas (*e.g*., inside of bends in the river);
- Rock and gravel are often found along the river edge associated with bulkheads and riprap; and,
- Riverbed substrate consists primarily of sand and gravel (with large rock and boulders) upstream from the vicinity of the 8th Street Bridge (~RM 15).

The study conducted by Aqua Survey, Inc. (2005b) also included the collection of 28 benthic infaunal samples at locations evenly distributed throughout the 17 mile study area; samples were collected at approximately 25% of the locations where Sediment Profile Imaging (SPI) data were also collected (Germano and Associates, Inc., 2005). This evaluation supports the following conclusions:

- The benthic macroinvertebrate community throughout the study area is characterized by low taxonomic diversity (species richness ranged from 2-9 and 1-10 in the freshwater [upper] and brackish, estuarine [lower] sections, respectively);
- As is characteristic of degraded estuarine environments, the community at most locations is dominated by one or two taxa that are tolerant to environmental stress (the dominant taxon comprised up to 91.8% [chironomids] and 100% [oligochaetes] of the samples in the freshwater and brackish sections, respectively);

[1] Further information is anticipated following completion of the 2006 WRDA field sampling program (including habitat characterization and biota survey work).

- Results of the SPI suggest that the benthos in the river exists in a state of flux due to relative substrate instability. Successional status is variable both within and between successive transects; there is also evidence that the infauna are continually at risk of being buried by newly deposited sediments;
- The benthic community in the freshwater section is dominated by chironomids (midge fly larvae), amphipods (*Gammarus* sp.), and oligochaetes; in the brackish section, oligochaetes and polychaetes dominate;
- Abundance appears to be highly variable with a range of 5-967 organisms/sample across the entire study area; and,
- Results for the lower section appear comparable to community data collected by TSI in Fall 1999/Spring 2000.

These data indicate that, with respect to the benthic community, there is a high degree of variability, both in terms of diversity and spatial distribution, along the river. These attributes of the system will be considered in the development of the BERA and associated sample design for the Field Sampling Plan (FSP) Volume 2.

Exposure Pathways Analysis

The preliminary exposure pathway analysis was presented in the Passaic River PAR (Battelle, 2005a). Figure 3 provides a slightly refined exposure model to better account for the potential exposures to benthivorous, omnivorous, and piscivorous avian and mammalian receptors. In addition, emergent vegetation was added as a receptor group, due to the direct exposure to sediment and the critical role that the plant community plays in habitat quality. Each of these groups, and the associated selection of the receptors of concern, will be evaluated further in the data quality objective (DQO) process.

Receptors of Concern

This section presents the updated list of wildlife receptors that was agreed upon during the BERA Workshop, in December 2005. This workshop was attended by a number of stakeholders including US Fish and Wildlife Service (USFWS), NJDEP, US Army Corps of Engineers (USACE), and representatives of the Potentially Responsible Parties (PRPs). Although the receptors were discussed and agreed upon by many parties involved in the project, the list may be further refined and updated following essential habitat surveys under the WRDA component of the restoration project.

Although there has been anecdotal evidence of the presence of many receptors along the Passaic River, the species data currently available are based primarily on quantitative studies conducted in the lower six miles of the river (e.g., TSI, 2002; Iannuzzi and Ludwig, 2004). Furthermore, current physical conditions in the river may not be supportive of specific habitat requirements for some recommended receptors (e.g., oysters), even though the species is known to have historically been present. Extensive habitat and field surveys will provide more evidence on whether such species could potentially exist following cleanup of the river. A Natural Resource Damage Assessment (NRDA) may be used to identify such additional actions, beyond cleanup, to address injuries to natural resources. Examples include actions needed to restore the productivity of habitats or species diversity that were injured by past releases or to replace them with substitute resources.

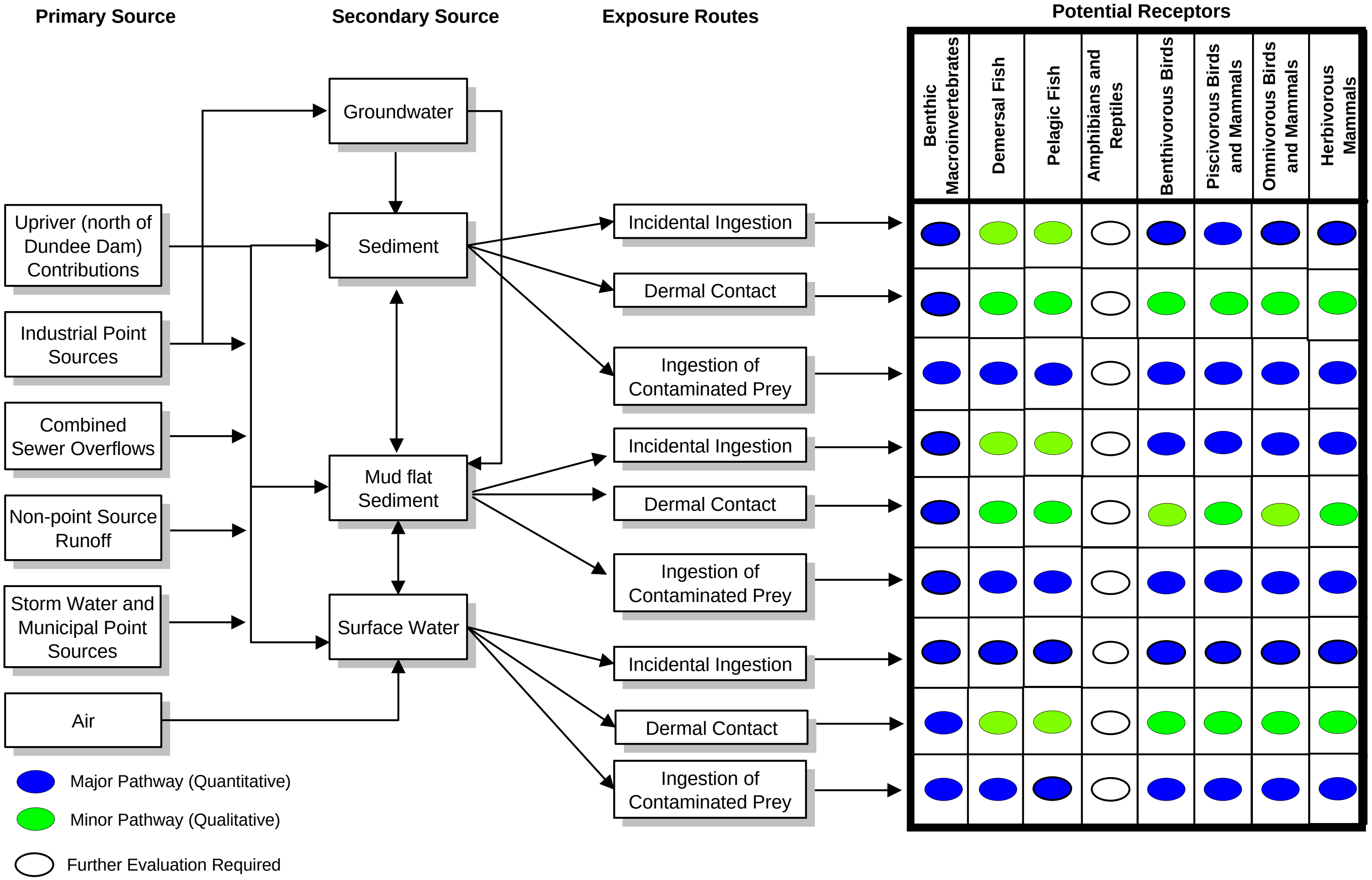

Figure 3. Conceptual Site Model for the Lower Passaic River

This section describes the potential receptors in detail, including life history information, habitat requirements, and potential foraging ranges. The list of selected receptors of concern (ROCs) is provided in Table 1. The Geochemical Evaluation (Malcolm Pirnie, 2006) and the associated CSM characterizes the river into three sections (estuarine, transitional, and freshwater) to assess chemical fate and transport. These segments are important to assess contaminant fate and transport mechanisms and to quantify sediment transport processes. The risk assessment activities will rely on these modeling efforts to assess chemical exposures to selected ROCs. However, only two sections of the river are relevant for consideration in the ecological CSM. There are no aquatic species that are specific to the transitional zone; the receptors of concern consist of estuarine species and freshwater species. The exceptions to this are avian and mammalian species with large foraging or home ranges that are capable of utilizing the entire study area. Consensus on these groupings was reached by the participating agencies and stakeholders during the BERA workshop.

The life histories of the selected species are provided in Table 2 (aquatic receptors) and Table 3 (wildlife receptors). A site-specific foraging range was determined for wildlife receptors based on available information in the literature for home ranges as well as assumptions about nesting areas and suitable foraging habitat in the vicinity of the site (Table 4). Mudflat locations and habitats are described in detail in Table 5 and shown as red squares in Figures 4 though 6.

Table 1. Receptors of Concern for the BERA

<table>
<tr><th>Receptor Group</th><th>Estuarine Receptor</th><th>Freshwater Receptor</th></tr>
<tr><td>Plants</td><td>Cord grass (Spartina sp.)</td><td>Spatterdock (Nuphar sp.)</td></tr>
<tr><td>Zooplankton Community</td><td>NA</td><td>NA</td></tr>
<tr><td>Benthic Invertebrate</td><td>Community</td><td>Community</td></tr>
<tr><td>Molluscs</td><td>Oyster (Crassostrea virginica)</td><td>NA</td></tr>
<tr><td>Crustaceans</td><td>Blue crab
(Callinectes sapidus)</td><td>Crayfish species</td></tr>
<tr><td>Fish (demersal)</td><td>Mummichog
(Fundulus heteroclitus)
Atlantic Silverside
(Menidia menidia)
Striped killifish (Fundulus majalis)</td><td>Catfish, channel (Ictalurus punctatus)
or brown bullhead (Ameiurus nebulosus)
Common Carp (Cyprinus carpio)</td></tr>
<tr><td rowspan="2">Fish (pelagic)</td><td>White perch
(Morone Americana)</td><td>Largemouth bass
(Micropterus salmoides)</td></tr>
<tr><td colspan="2">Striped bass(Morone saxatilis)
American eel (Anguilla rostrata)</td></tr>
<tr><td>Amphibian</td><td>NA</td><td>Bullfrog (Rana catesbeiana)</td></tr>
<tr><td>Reptile</td><td>NA</td><td>Snapping turtle (Chelydra serpentina)</td></tr>
<tr><td>Bird (piscivorous)</td><td colspan="2">Herring gull (Larus argentatus)
Belted kingfisher (Ceryle alcyon)
Great egret (Ardea alba)
Double-crested cormorant (Phalacrocorax auritus)</td></tr>
<tr><td>Bird (omnivorous)</td><td colspan="2">Mallard duck (Anas platyrhynchos)</td></tr>
<tr><td>Bird (benthivorous)</td><td colspan="2">Spotted sandpiper (Actitis macularia)</td></tr>
<tr><td>T&E Bird Species</td><td colspan="2">Black-crowned night heron (Nycticorax nycticorax)
Peregrine falcon (Falco peregrinus)
Osprey (Pandion haliaetus)</td></tr>
<tr><td>Mammal (piscivorous)</td><td colspan="2">Mink (Mustela vison)</td></tr>
<tr><td>Mammal (omnivorous)</td><td colspan="2">Raccoon (Procyon lotor)</td></tr>
<tr><td>Mammal (herbivorous)</td><td colspan="2">Muskrat (Ondatra zibethicus)</td></tr>
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Table 2. Life History and Ecology of Aquatic Receptors in the Passaic River

Species	Habitat Requirements	Foraging Habits
White perch (*Perca flavescens*)	• Prefer shallow areas and tributaries, generally staying close to rooted vegetation. • Bottom-oriented fish that accumulate in areas with dissolved oxygen of at least 6 mg/L (Setzler-Hamilton, 1991). • Gladden et al. (1988) found the majority of white perch, over the course of three years in the Hudson River, to prefer the main channel bottom. • Adults tend to accumulate at 4.6-6 m depth during the day and move back to the surface at night (Setzler-Hamilton, 1991). • During the winter, white perch are found in depths of 12-18 m, but can be found at depths as low as 42 meters. • In the Hudson River, Carlson (1986) found white perch as far up as river mile 102 to 131 in the summer, where spawning occurs. By winter, the majority of white perch move down river. • All ages of fish are adversely affected by high levels of suspended solids and avoid areas with moderate turbidity at 45 NTU.	• Adults forage on benthic invertebrates, with older fish becoming increasingly piscivorous (Setzler-Hamilton, 1991). • Insect larvae and fish comprise the principal diet of white perch, with chironomids representing the most important insect prey and amphipods such as *Gammarus* sp. representing second most common dietary item.

Table 2. Life History and Ecology of Aquatic Receptors in the Passaic River (continued)

Species	Habitat Requirements	Foraging Habits
Largemouth bass (*Micropterus salmoides*)	• Has a tolerance for high temperatures and slight turbidity (Scott and Crossman, 1973). • Occupies waters with abundant aquatic vegetation. • Shows a tolerance for low oxygen conditions. • Have distinct home ranges and are found between 8 and 9 km of their preferred range (Kramer and Smith, 1960). • Kramer and Smith (1960) found that 96% of fish remained within 91 m of their nesting range. • Fish and Savitz (1983) found that bass in Cedar Lake, IL, have home ranges from 1,800 to 20,700 sq meters. The average home range was 9,245 sq meters; with the primary occupation area (the portion of the home range in which the fish spends the majority of its time, including foraging) was 6,800 sq meters. • Associated with soft bottoms, stumps, and extensive growths of emergent and submerged vegetation, particularly water lilies, cattails, and various species of pond weed. • Unusual to find largemouth bass in rocky areas.	• Johnson (1983) found that diets of juvenile fish in the St. Lawrence River varied by location and length of the fish; fish, insects, and other invertebrates made up the diet in varying proportions. • Fish longer than 50 mm total length forage exclusively on smaller fish such as gizzard shad, carp, and silversides (Scott and Crossman, 1973). • Cannibalism is present among largemouth bass, with 10% of the food of fish at least 20 mm consisting of their own fry (Scott and Crossman, 1973). • Forage by sight, often in schools, near shore, and close to vegetation. • Crayfish and frogs are also occasional prey of largemouth bass (Exponent, 1998a and 1998b).
Striped bass (*Morone saxatilis*)	• Anadromous species that enters rivers to spawn and then returns back to the sea. • Juveniles remain in rivers until their second year when they begin their annual migration offshore (NOAA, 1985). • Striped bass have been observed in the Hudson River up to river mile 100 to 150; peak catches of young-of-the-year fish have been collected at river mile 35 (LMS, 1992).	• Voracious, carnivores who feed in schools. • A study by Hudson River power authorities (Texas Instruments, 1980) found that striped bass up to 75 mm prefer amphipods such as *Gammarus* sp. and chironomid larvae. Fish from 76 to 125 mm preferred *Gammarus* sp and calanoid copepods. Those from 126 to 200 mm preferred a fish prey, *Microgadus* tomcod, but may also consume mummichog, mullet, and white perch. • Fish make up the bulk of the diet of adult fish.

Table 2. Life History and Ecology of Aquatic Receptors in the Passaic River (continued)

Species	Habitat Requirements	Foraging Habits
Brown bullhead (*Ictalurus nebulosus*)	• Very tolerant of conditions of temperature, oxygen, and pollution (Scott and Crossman, 1973). • In the summer, bullheads can be found in coves with ooze bottoms and lush vegetation; especially water clover, spatterdock, and several species of pond weed. • Prefers silty bottoms and slow currents. • Most frequently found in wetland and embayment habitats (MPI, 1984).	• Demersal, omnivorous species that feeds off the bottom in shallow, warm water areas, with abundant aquatic vegetation and sand to mud bottoms. • Diet consists mainly of benthic invertebrates, such as oligachaete worms and crustaceans (LMS, 1975). •
Atlantic silverside (*Menidia menidia*)	• Spawning areas are seaward of locations used by Inland silversides (*Menidia beryllina*), a closely related species (Smith, 1971). • During the spring and summer, silversides have been reported as the most abundant species in marsh and estuarine habitats, yet they may be absent from the same areas in the winter (Fay et al., 1983). • A NMFS survey captured 86% of silversides at depths less than 50 m and water temperatures between 36°C and 43°C (Conover and Murawski, 1982).	• Important forage fish for striped bass, Atlantic mackerel, and bluefish. • Feed in large schools in gravel and sand bars, open beaches, tidal creeks, river mouths, and flooded zones of marsh vegetation (Bayliff, 1950; Bigelow and Schroeder, 1953).
American eel (*Anguilla rostrata*)	• Spends most of its life in estuaries, rivers, and lakes, and returns to the sea to spawn. • Estimates of the home range of eels extend to 3.4 ha in small streams, tidal rivers, and tidal creeks; from 2.4 to 65.4 ha in a large lake; <100 m along a tidal creek (Facey and Van den Avyle, 1987). • Post-larval eels are bottom dwellers and hide in burrows, tubes, snags, plant masses, or the substrate itself (Fahay, 1978). • The presence of soft, undisturbed living space is important to migrating eels.	• An important food source for larger marine and freshwater fish. • Preys on a variety of other species including crabs and clams. • Eels in freshwater feed on insects, worms, crayfish and other crustaceans, frogs, and fish. • Crustaceans, bivalves, and polychaetes were the major prey of eels in the lower Chesapeake Bay (Wenner and Musick, 1975).

Table 2. Life History and Ecology of Aquatic Receptors in the Passaic River (continued)

Species	Habitat Requirements	Foraging Habits
Mummichog (*Fundulus heteroclitus*) and Striped killifish (*Fundulus majalis*)	• Both species are instrumental in salt marsh habitats in movement of organic material within and out of salt marsh ecosystems (Kneib et al., 1980). • The mummichog is one of the "most stationary of fishes" (Bigelow and Schroeder, 1953). • Mummichogs over 60 mm long maintain a summer home range of 36-38 m along one bank of tidal creeks; however, some may move as much as 375 m (Lotrich, 1975). • In winter, mummichogs burrow 150-200 mm into the mud (Chidester, 1920; Hardy, 1978) or migrate to the mouth of the tidal channel and then migrate up the channel in the spring (Butner and Brattstrom, 1960). • Striped killifish tend to occur over sandy sediments more often than mummichogs do. • Striped killifish may be found in water only a few centimeters deep and are concentrated generally along the shoreline during low tides. • In North Carolina and the Chesapeake Bay, mummichogs are found to be more tolerant of lower salinities than striped killifish; however, the habitats of these species do overlap (Hildebrand and Schroeder, 1928; Peterson and Peterson, 1979). • Mummichogs are considered to be stress- and pollutant-tolerant, and can survive in very low oxygen habitats.	• Utilize all potential food sources: water-column organisms, subtidal benthos, and intertidal benthos (Weisberg and Lotrich, 1982). • Common food source is grass shrimp (Heck and Thoman, 1981). • Crustaceans and polychaetes found to be the most common food items (Baker-Dittus, 1978). • Preyed upon by American eels, white perch, and summer flounder. • Also serve as prey for wading and piscivorous birds.

Table 2. Life History and Ecology of Aquatic Receptors in the Passaic River (continued)

Species	Habitat Requirements	Foraging Habits
Blue crab **(*Callinectes sapidus*)**	• Most blue crabs migrate to relatively deeper, warmer waters during the winter and return to rivers, tidal creeks, and salt marshes, when conditions become more favorable in the spring (Livingston, 1976). • Tagged female crabs have occasionally been recovered 100-540 km from their release sites (Van den Avyle, 1984). • Occupy waters ranging from 34 ppt to freshwater rivers as far as 195 km upstream (Tagatz, 1968). • Shallow salt marsh habitats are important for juveniles. • When not mating, females tend to remain in higher salinities of lower estuaries and surrounding waters (Van den Avyle, 1984). • Adkins (1972) found the optimum habitat for small crabs to be shallow estuarine waters with soft, detrital bottoms; larger crabs prefer deeper waters with hard substrates.	• Consumes plankton, small invertebrates, fish, and other crabs. • Important detritivore and scavenger. • Darnell (1958) concluded that mollusks became the dominant food item of crabs larger than 120 mm in width.
Channel catfish **(*Ictalurus punctatus*)**	• Live in moderate to swiftly flowing streams, but are also abundant in large reservoirs, lakes, ponds and sluggish streams. • Usually found where bottoms are sand, gravel or rubble, in preference to mud bottoms; seldom found in dense aquatic weeds. • Typically a freshwater fish but can thrive in brackish water. • Generally prefer clear water streams, but are common and do well in muddy water. • Found in deep holes wherever the protection of logs and rocks can be found (Wellborn, 1988).	• Most movement and feeding activity occurs at night just after sunset and just before sunrise. • Young fish frequently feed in shallow riffle areas, while adults feed in deeper water immediately downstream from sand bars. • Adults are sedentary, while young fish tend to move about much more extensively, particularly at night when feeding (Wellborn, 1988). • Young catfish feed primarily on aquatic insects; adults have a much more varied diet which includes insects, snails, crawfish, green algae, aquatic plants, seeds and small fish.

Table 3. Wildlife Receptors in the Lower Passaic River

Wildlife Receptor	Home Range (location of study/habitat)	Primary Reference	Habitat Preference	Primary Reference	Seasonal Variability	Primary Reference
Piscivorous Birds						
Herring gull (*Larus argentatus*)	Foraging radius: 3-25 km (Not stated/coastal)	Pierotti, pers. Comm. (USEPA, 1993)	• Nesting colonies along the northeastern US are found mainly on sandy or rocky offshore or barrier beach islands • Smaller colonies can be found in coastal marshes, peninsulas, or cliffs along seacoasts, lakes, rivers, and inland on buildings and piers • Forage offshore, generally within 1-5 km of the coast • Found predominantly inshore during the breeding season in spring and summer, where they forage in intertidal zones but also in wet fields, lakes, bays, rock jetties, and landfills	Kadlec and Drury, 1968 Weseloh, 1989 Burger, 1980 Harris, 1964	• In the western North Atlantic, herring gulls arrive on their breeding grounds in early spring and remain until autumn, when they leave for their wintering grounds along the Gulf coast or well offshore • Observed year-round in Lower Passaic River	Powers, 1983 Pierotti, 1988 Burger, 1982 TSI, 2002
Great egret (*Casmerodius albus*)	Home range: 8-32 km (North Carolina, California/island, bay)	Ives, 1973 Yull, 1972 Custer and Osborn, 1978	• Inhabits freshwater and marine areas such as freshwater rivers, brackish marshes, lagoons, and coastal wetlands • Prefers areas where small fish are plentiful and water is shallow, such as tidal flats and sandbars • Nests in dense colonies close to foraging grounds • Tall trees near water are preferred over shorter trees or bushes for nesting sites • Nesting colony must be isolated from human activities, or parents may abandon nests	Splendelow and Patton, 1988 Short and Cooper, 1985 Palmer, 1962 Bent, 1926 Gibbs et al., 1987 Ives 1972, 1973 Cogswell,1977	• Favored wintering grounds are mainly mangroves, mudflats, estuaries • Breeds in coastal areas of the US, Mexico, and South America • Observed in Lower Passaic River during spring, summer, and autumn; migrates South for winter months	Hancock and Kushlan, 1984 Robbins et al., 1983 National Geographic Society, 1987 Palmer, 1962 Short and Cooper, 1985 TSI, 2002

Table 3. Wildlife Receptors in the Lower Passaic River

Wildlife Receptor	Home Range (location of study/habitat)	Primary Reference	Habitat Preference	Primary Reference	Seasonal Variability	Primary Reference
Belted kingfisher (*Ceryle alcyon*)	Territory size: 0.39 - 2.19 km of shoreline (Ohio and Pennsylvania/streams)	Brooks and Davis, 1987 Davis, 1980	• Common on seacoasts and estuaries • Prefers rivers and streams that are free of thick vegetation • Requires clear water and avoids waters that are turbid • Burrows in sandy soil banks that are easy to excavate and provide good drainage • Fishes from upper 12-15 cm of water column • Nests in burrows within steep earthen banks devoid of vegetation near rivers, streams, and lakes • Also nests in slopes created by human excavations such as roadcuts and landfills	Bent, 1940 White, 1953 Davis, 1982 Salyer and Lagler, 1946 Hamas, 1974	• Breeding areas utilized during the spring and summer can be more than twice as long as the feeding areas utilized during the fall and winter • Although most migrate to southern regions during the coldest months, some stay in areas that remain ice-free where fishing is possible • 32 individuals were observed in the Lower Passaic River area during winter 2005; likely a year-round resident	Davis, 1982 Salyer and Lagler, 1946 Bent, 1940 Audubon, 2006
Black-crowned night heron (*Nycticorax nycticorax*) T&E Species	Foraging range: 0-8 km (North Carolina)	Custer and Osborn, 1978	• Common in freshwater swamps and tidal marshes • Roosts in trees during the day, feeds at night • Nest-sites usually in dense-foliaged trees, dense, fresh or brackish emergent wetlands near aquatic or emergent feeding areas, but nonbreeding-season roosts may be farther away • Islands created through the deposition of dredged material may provide nesting and roosting habitat when revegetated.	Grinnell and Miller, 1944 CDFG, 2003	• Breeding occurs over much of the US and parts of central Canada • Winters along both coasts of the US and farther South • Observed in Lower Passaic River area in spring, summer, autumn; likely migrates South during coldest months	Hancock and Kushlan, 1984 Robbins et al., 1983 National Geographic Society, 1987 Palmer, 1962 Short and Cooper, 1985 TSI, 2002

Table 3. Wildlife Receptors in the Lower Passaic River

Wildlife Receptor	Home Range (location of study/habitat)	Primary Reference	Habitat Preference	Primary Reference	Seasonal Variability	Primary Reference
Double-crested cormorant (*Phalacrocorax auritus*)	Foraging range: 8-16 km	Palmer, 1962	• Rests in daytime and roosts overnight beside water on offshore rocks, islands, steep cliffs, dead branches of trees, wharfs, jetties, or even transmission lines • Perching sites must be barren of vegetation • May rest or sleep on water in daytime • Requires considerable length of water, or elevated perch, for labored take-off • Requires undisturbed nest-sites beside water, on islands, or mainland • Dives from water surface and pursues prey underwater • Prefers water less than 9 m deep with rocky or gravel bottom, but may catch fish as deep as 22 m	Bartholomew, 1943 Palmer, 1962	• Breeds mostly April to July or August, most laying is April to June • Nests in colonies of a few to hundreds of pairs, or even thousands • Observed in Lower Passaic River area year-round	CDFG, 2003 TSI, 2002 Audubon, 2006
Omnivorous Bird						
Mallard duck (*Anas platyrhynchos*)	Home range: 40-1440 ha (Minnesota/wetlands, river)	Kirby et al., 1985	• Prefers natural bottomland wetlands with water depths of 20-40 cm • Prefers dense grassy vegetation at least one-half meter high for nesting • Prefers areas that provide concealment from predators (*e.g.*, seeded cover, cool-season legumes and grasses, and idle grassland) • Nests are generally located within a few kilometers of water	Heitmeyer, 1985 Allen, 1987 Bellrose, 1947 Klett et al., 1988 Lokemoen et al., 1990b Dubbert and Lokemeon, 1976 Duebbert and Kantrud, 1974	• In spring, females shift from a largely herbivorous diet to one of mainly invertebrates • Females that reproduce successfully are likely to return to the same nesting ground the following year • Ducks winter farther north than in the past in North America due to human alteration of water and plant communities • Observed in Lower Passaic River area year-round	Jorde et al., 1983 Lokemoen et al., 1990a, 1990b TSI, 2002 Audubon, 2006

Table 3. Wildlife Receptors in the Lower Passaic River

Wildlife Receptor	Home Range (location of study/habitat)	Primary Reference	Habitat Preference	Primary Reference	Seasonal Variability	Primary Reference
Benthivorous Birds						
Spotted sandpiper (*Actitis macularia*)	Territory size: 0.39-2.19 km of shoreline (Ohio and Pennsylvania/streams)	Maxson and Oring, 1980	• Forages on sandy beaches and mudflats • Young feed on small invertebrates immediately after hatching • Nests are placed in semi-open vegetation near the edge of lakes, rivers, or oceans • Requires open water for bathing and drinking, semi-open for nesting, and dense vegetation for breeding	Oring et al., 1983 Oring and Lank, 1986 Bent, 1929	• Migrant in US, wintering in the tropics and breeding north of Virginia and southern California • Observed in Lower Passaic River area in spring, summer, and autumn; likely migrates south during coldest months	National Geographic Society, 1987 TSI, 2002 Audubon, 2006
Raptors						
Peregrine falcon (*Falco peregrinus*) T&E Species	Home range: 23-27 km (Utah, Canada/Rocky Mountains)	Northwest Territory Canada, Environment and Natural Resources, Wildlife Division, webpage updated 2005 Polite and Pratt, 2003	• A rare resident of woods, mountains, and coasts • Preys almost exclusively on birds • Nests in urban environments in some States • 19 known pairs in NJ • Artificial nesting platforms were erected in coastal marshes in NJ, where they now nest • Peregrine falcons favor open areas for foraging and often hunt over marshes, beaches or open water	Cade, 1982 Craighead and Craighead, 1956 National Geographic Society, 1987 Brown and Amadon, 1986 NJDEP, 2003	• Found wintering in most States	Cade, 1982 Craighead and Craighead, 1956 National Geographic Society, 1987 Brown and Amadon, 1986

Table 3. Wildlife Receptors in the Lower Passaic River

Wildlife Receptor	Home Range (location of study/habitat)	Primary Reference	Habitat Preference	Primary Reference	Seasonal Variability	Primary Reference
Osprey (*Pandion haliaetus*) T&E Species	Foraging radius: 3-10 km (Nova Scotia, California/coastal, bay)	Greene et al., 1983 Koplin, 1981	• Good nesting sites are close to open, shallow water with plentiful fish • The tops of isolated and dead trees and man-made structures are preferred nesting sites • In the Chesapeake Bay area less than one-third build in trees, most are on channel markers and other man-made structures • Where good nesting sites are scarce, breeding is often delayed until 4-7 years of age • Forage by catching species of slow-moving fish that eat benthic organisms in shallow waters, and fish that remain near the surface	Poole, 1989 Henney et al., 1974	• After their first migration south, juveniles remain there for a year and a half, and return North to the breeding grounds as 2-year olds • Observed only in autumn in Lower Passaic River area	Henny and Van Velzen, 1972 TSI, 2002
Piscivorous Mammal						
Mink (*Mustela vison*)	Home range: 7.8 ha (heavy vegetation)-20.4 ha (sparse vegetation) (Montana/riverine); 1.0-2.8 km (Sweden/stream)	Mitchell, 1961 Gerell, 1970	• Prefers irregular shorelines to more open, exposed banks • Uses brushy or wooded cover near the water where cover for prey is abundant and debris provide den sites • Shorelines and emergent vegetation are the principal hunting areas • Females are limited to smaller prey than males, who hunt rabbits and muskrats	Allen, 1986 Arnold, 1986 Eagle and Whitman, 1987	• In winter, the diet is supplemented with fish • In marsh habitats in summer, muskrats are an important food source • In high water, mink capture crayfish and voles • In low water, mink capture aquatic birds and muskrats deeper in the marsh	Proulx et al., 1987 Hamilton, 1940 Sealander, 1943 Errington, 1954 Birks and Dunstone, 1985 Eagel and Whitman, 1987

Table 3. Wildlife Receptors in the Lower Passaic River

Wildlife Receptor	Home Range (location of study/habitat)	Primary Reference	Habitat Preference	Primary Reference	Seasonal Variability	Primary Reference
Omnivorous Mammal						
Raccoon (*Procyon lotor*)	Home range: 5.3-376 ha (Michigan/riparian, May-Dec)	Stuewer, 1943	• Permanent water supply, tree dens, and available food are essential • Uses surface waters for both drinking and foraging • Found near virtually every aquatic habitat • Common in suburban residential areas and farmlands • Omnivorous and opportunistic feeder	Kaufmann, 1982 Greenwood, 1982 Stuewer, 1943	• In spring and early summer, raccoons consume more animal than plant material • Late summer and fall diets consist of mainly fruits • Hibernate in winter for up to four months • Wintering home ranges are smaller than those during other times of the year	Stuewer, 1943 Kaufmann, 1982
Herbivorous Mammal						
Muskrat (*Ondatra zibethicus*)	Home range: 0.17 ha (Iowa/marsh)	Neal, 1968	• Inhabits saltwater and brackish marshes and freshwater creeks, streams, lakes, marshes, and ponds • Typically excavates dens in the banks along streams and rivers • Feeds on aquatic vegetation near their homes • Young muskrats feed more on bank vegetation than adults, who also dig for food on lake and pond bottoms	Dozier, 1953 Johnson, 1925 Kiviat, 1978 O'Neil, 1949 Perry, 1982	• Breeding occurs in the spring and summer	Errington, 1963 Mathiak, 1966 Beer, 1950 Gashwiler, 1950

Table 3. Wildlife Receptors in the Lower Passaic River

Wildlife Receptor	Home Range (location of study/habitat)	Primary Reference	Habitat Preference	Primary Reference	Seasonal Variability	Primary Reference
Reptile						
Snapping Turtle (*Chelydra serpentina*)	Home range: 2.5-7.2 ha (Canada/lake, New York/fresh tidal wetland)	Obbard and Brooks, 1981 Kiviat, 1980	• Inhabits freshwater and brackish habitats • Most often found in turbid waters with a slow current • Spends most of its time lying on bottom of deep pools or buried in the mud in shallow water • Nest-sites may be in the soil of banks or in muskrat houses, but more commonly is in the open on south-facing slopes and may be several hundred meters from the water • Most turtles stay primarily within the same marsh or in one general area from year to year	Graves and Anderson, 1987 Froese, 1978 DeGraaf and Rudis, 1983	• In the spring, when there is limited vegetation, eat primarily animal matter, but when more aquatic vegetation becomes abundant, they become more herbivorous • Young are carnivorous and prefer smaller streams where vegetation is less abundant, they migrate to habitats preferred by adults (e.g., marshes, ponds, lakes) at maturity • Hibernate in the fall by burrowing into debris or mud bottom and emerge in the spring	Pell, 1941 Graves and Anderson, 1987 Lagler, 1943 Hammer, 1969 Obbard and Brooks, 1981 Hammer, 1971 Minton, 1972
Amphibian						
Bullfrog (*Rana catesbeiana*)	Home range: 0.61-10.2 m radius (Canada/pond)	Currie and Bellis, 1969	• Lives at edges of ponds, lakes, and streams with sufficient vegetation to provide cover • Smaller frogs favor areas of shallow water where short grasses or other vegetation or debris provide cover • Tadpoles congregate around green plants • Eggs are attached to submerged vegetation	Behler and King, 1979 Durham and Bennett, 1963 Jaeger and Hailman, 1976 Bury and Whelan, 1984	• Hibernation begins in the fall, when they bury under water in mud and leaves • Temperatures above 32°C have been shown to cause abnormalities in tadpoles and above 35.9°C to kill embryos • Tadpole growth rates increase with increasing oxygen levels, food availability, and water temperature • Tadpoles metamorphose in 1 to 3 years	Howard, 1978 Bury and Whelan, 1984 DeGraaf and Rudis, 1983 Martof et al., 1980

Table 4. Standardized Home Ranges of Wildlife Receptors along the Lower Passaic River.

Wildlife Receptor	Conservative Home Range (literature)	Habitat Assumptions	Primary Foraging Method	Conservative Home Range (standardized to river length)	Notes
Birds					
Herring gull	25 km radius (15.5 mi) USEPA, 1993	Nests in Meadowlands and/or Shooters Island	Wader, diver, scavenger	17 mi (entire study area)	Due to the large home range radius of the herring gull (15.5 mi), birds nesting in the Meadowlands could forage along the upper reaches of the study area. Birds nesting on Shooters Island likely use the lower 10 miles of the river; therefore, the entire river could be utilized for foraging by this species.
Belted kingfisher	2.19 km of shoreline (1.36 mi) USEPA, 1993	Nests along Passaic River in areas that are free from thick vegetation; burrows in sandy areas, near calm water	Diver	1.36 mi (along any part of the river)	Although the belted kingfisher has a relatively small home range (1.36 mi), it has been observed in all portions of the lower 6 miles of the river (TSI, 2002) and is also likely present in the upper reaches of the river.
Great egret	32 km (20 mi) USEPA, 1993	Nests on Shooters Island; forages on mudflats and sandbars	Wader	14 mi (lower 14 mi of study area)	The great egret is a colonial estuarine bird that is assumed to nest on Shooters Island because it requires nesting sites away from human activities. Shooters Island is located approximately 6 miles south of the Passaic River, in Newark Bay; therefore its home range is likely the lower 14 miles of the river.

Table 4. Standardized Home Ranges of Wildlife Receptors along the Lower Passaic River (continued)

Wildlife Receptor	Conservative Home Range (literature)	Habitat Assumptions	Primary Foraging Method	Conservative Home Range (standardized to river length)	Notes
Double-crested cormorant	16 km (10 mi) CDFG, 2003	Nests on Shooters Island and/or Meadowlands	Diver	10 mi (lower 10 miles of study area)	Birds nesting on Shooters Island, which is located 6 miles south of the Passaic River, likely utilize the lower 4 miles of the river. Birds nesting in the Meadowlands are capable of utilizing more upstream portions of the river; therefore the home range is assumed to be the lower 10 miles of the study area.
Mallard duck	1440 ha (5560 sq mi) USEPA, 1993	Nests in Meadowlands and/or along vegetative portion of Passaic River	Dabbler	17 mi (entire study area)	Although the mallard duck is primarily a freshwater species, it has been observed throughout the year in the lower 6 miles of the Passaic River (TSI, 2002). Therefore, it is assumed that the mallard duck uses the entire 17-mile study area.

Table 4. Standardized Home Ranges of Wildlife Receptors along the Lower Passaic River (continued)

Wildlife Receptor	Conservative Home Range (literature)	Habitat Assumptions	Primary Foraging Method	Conservative Home Range (standardized to river length)	Notes
Black-crowned night heron	8 km (5 mi) CDFG, 2003	Nests in and around the Meadowlands in dense foliaged trees	Stalker, diver	5 mi (along any part of the river)	Although Shooters Island is a known resting area for night herons, their small home range (5 mi) indicates that birds nesting on the island would not likely forage as far north as the Passaic River. In addition, these birds require dense foliaged trees or wetlands for nesting, which are limited along the Passaic River. Therefore, it can be assumed that birds foraging along the river are nesting in and around the Meadowlands. The avian survey (TSI, 2002) indicated that night herons are found throughout the lower 6 miles of the Passaic; thus, they likely forage along any and all parts of the river.
Spotted sandpiper	2.19 km of shoreline (1.36 mi) USEPA, 1993	Utilizes mudflats; nests along river	Wader	1.36 mi Exposed mudflats along entire river	Spotted sandpipers forage on sandy beaches and mudflats, digging and probing into the sediment for small aquatic invertebrates. Since the majority of mudflats along the study area are less than the home range (1.36 mi), they likely utilize the entire mudflat (Table 5).
Peregrine falcon	27 km (17 mi) CDFG, 2003		Diver	17 mi (entire study area)	Peregrine falcons have a 17-mile home range and therefore could potentially forage along the entire Passaic River study area.

Table 4. Standardized Home Ranges of Wildlife Receptors along the Lower Passaic River (continued)

Wildlife Receptor	Conservative Home Range (literature)	Habitat Assumptions	Primary Foraging Method	Conservative Home Range (standardized to river length)	Notes
Osprey	10 km radius (6.2 mi) USEPA, 1993	Nest on man-made structures in open water areas (*e.g.*, channel markers in Newark Bay)	Diver	3 mi (lower 3 mi of study area)	Osprey have been observed only in the lower 3 miles of the Passaic River (TSI, 2002), probably because they nest in made-made structures near open water, such as channel markers in Newark Bay. Also, their home range covers a small (6 mi) radius. Assuming they nest approximately 3 miles south of the mouth of the Passaic River in Newark Bay, away from boat traffic, their home range up the Passaic River, would encompass 3 miles.
Mammals					
Mink	20.4 ha (79 sq mi) USEPA, 1993			17 mi (entire study area)	Both mink and raccoon have large home ranges and could potentially forage along the entire study area.
Raccoon	376 ha (1452 sq mi) USEPA, 1993			17 mi (entire study area)	Both mink and raccoon have large home ranges and could potentially forage along the entire study area.
Muskrat	0.17 ha (0.66 sq mi) USEPA, 1993	Excavates dens in riverbanks; forages on mudflats		3500 sq ft (mudflats that are at least 350 ft long x 10 ft wide)	Muskrats utilize both freshwater and brackish areas, excavating dens in the banks along streams and rivers. Their relatively small home range (0.66 sq mi) indicates they stay near their den. Assuming they forage and nest in mudflat and cove areas of the Passaic River, they likely utilize areas that are around 3500 sq ft. If the mudflats are 10 ft wide, they would need to be at least 350 feet long, which includes many along the river.

Table 4. Standardized Home Ranges of Wildlife Receptors along the Lower Passaic River (continued)

Wildlife Receptor	Conservative Home Range (literature)	Habitat Assumptions	Primary Foraging Method	Conservative Home Range (standardized to river length)	Notes
Reptile					
Snapping turtle	7.2 ha (27.8 sq mi) USEPA, 1993	Inhabits freshwater habitats, which begin at mile 7		9 mi (river mile 7 to river mile 16)	Snapping turtles inhabit banks of the freshwater portion where there is slow current and turbid water, likely at river and stream confluences. It is assumed that they could utilize most of the freshwater portion of the river (9 mi), with the exception of the area immediately after the dam, which is likely too turbid.
Amphibian					
Bullfrog	10.2 m radius (33.5 ft) USEPA, 1993	Inhabits freshwater habitats, which begin at mile 7		33.5 ft (around CSOs, vegetated areas of the upper 10 miles)	Bullfrogs inhabit vegetated freshwater banks and have been observed in and around CSOs, which provide cover from predators (Stern USFWS, 2005 pers. comm.). Therefore, they are assumed to utilize small, vegetated areas around CSOs of the freshwater portion (upper 10 mi) of the river.

Assumptions:

- Length of Passaic River = 17 mi
- Average width ~550 ft = 0.10 mi
- Estuarine portion of river = 0-7 mi
- Freshwater portion of river = 7-17 mi
- Distance between Passaic River and Hackensack River (Meadowlands)~ 4 mi
- Distance between Passaic River and Shooter's Island ~ 6 mi

Table 5. Location of Mudflat Habitats along the Lower Passaic River

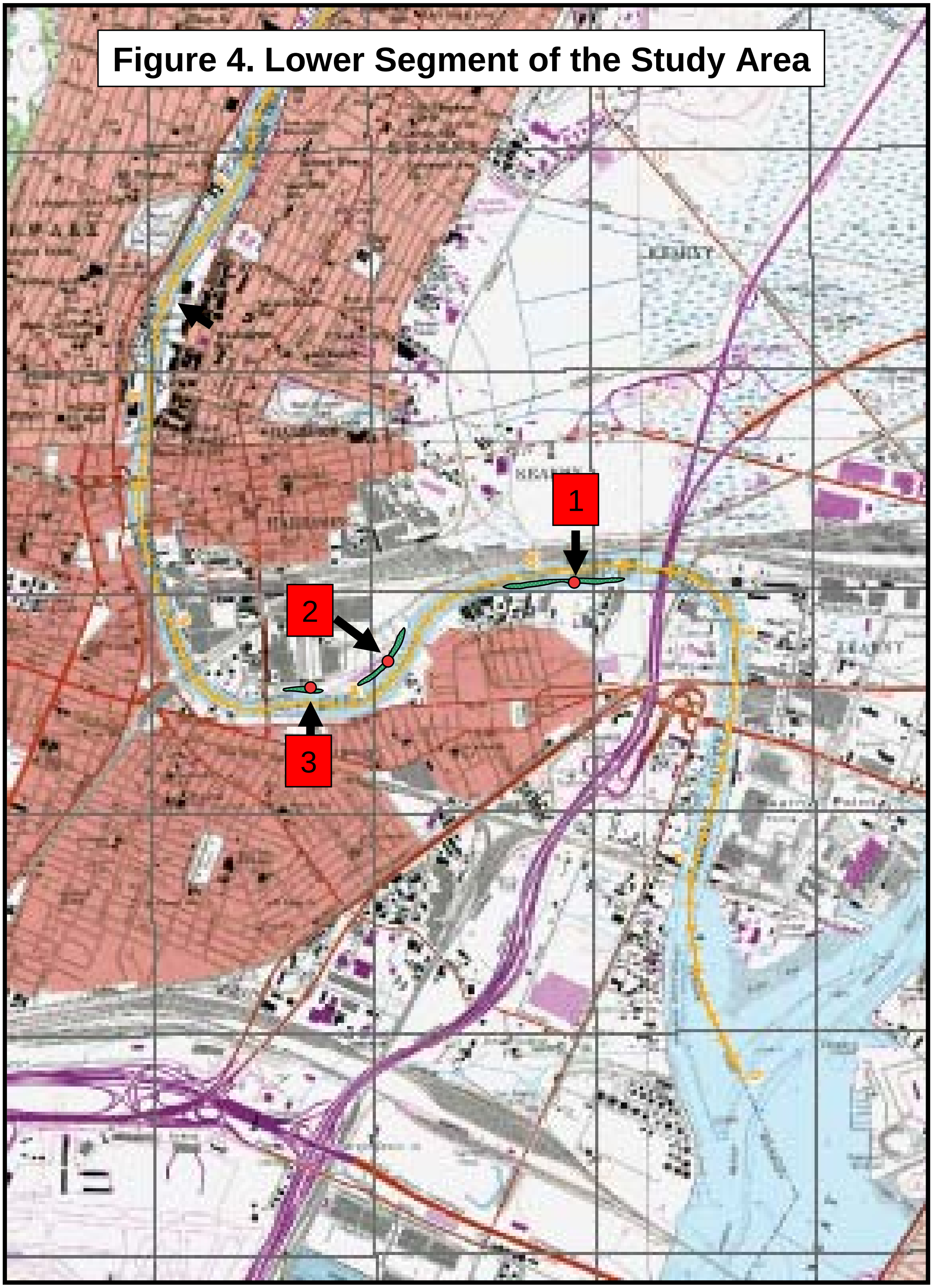
No[a]	Approximate River Mile (side)	Location	Ecological Habitat	Potential Wildlife Receptors
1	2.8-3.2 (L)	River bank in vicinity of the Diamond Shamrock facility	Bathymetry data indicate section of exposed mudflat habitat	Spotted sandpiper Great egret Herring gull Belted kingfisher Muskrat
2	3.5 (R)	Worthington Avenue CSO	Small cove area including wetland vegetation and unvegetated mudflats that provide cover and possible spawning habitat to aquatic receptors	Spotted sandpiper Great egret Herring gull Belted kingfisher Muskrat
3	4.2-4.3 (R)	Mouth of unnamed stream	Small habitat complex consisting of intertidal mudflat and artificial hard-bottom substrate	Spotted sandpiper Great egret Herring gull Belted kingfisher Muskrat
4	8.1 (L)	Mouth of Second River	Possible cove area and associated mudflats that provide cover and spawning habitat to aquatic receptors	Spotted sandpiper Great egret Herring gull Belted kingfisher Muskrat Snapping turtle Bullfrog
5	9.5-9.9 (R)	Mouth of Remnant Creek	Bathymetry data indicate section of exposed mudflat habitat	Spotted sandpiper Great egret Herring gull Belted kingfisher Muskrat Snapping Turtle
6	10.5-11.1 (R)	Edge of river downstream of confluence with Third Creek	Bathymetry data indicate section of exposed mudflat habitat	Spotted sandpiper Great egret Herring gull Belted kingfisher Muskrat
7	11.2 (L)	Mouth of Third Creek	Possible cove area and associated mudflats that provide cover and spawning habitat to aquatic receptors	Spotted sandpiper Great egret Herring gull Belted kingfisher Muskrat Snapping turtle Bullfrog

[a] See Figures 4, 5, and 6 for maps depicting mudflat locations.

Table 5. Location of Mudflat Habitats along the Lower Passaic River (continued)

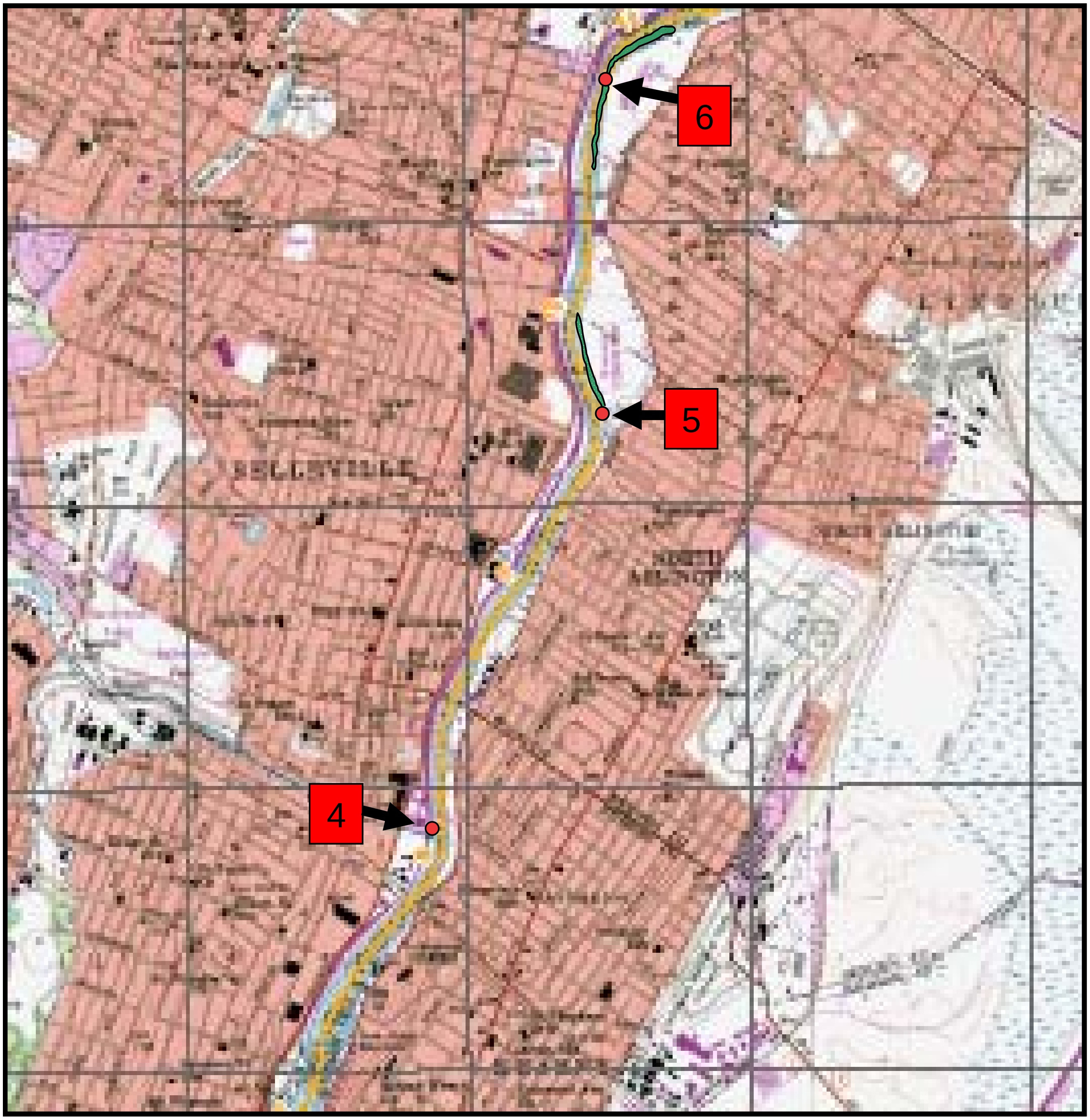
No[a]	Approximate River Mile (side)	Location	Ecological Habitat	Potential Wildlife Receptors
8	11.5 (R)	Edge of river upstream of confluence with Third Creek	Bathymetry data indicate section of exposed mudflat habitat	Spotted sandpiper Great egret Herring gull Belted kingfisher Muskrat
9	14.1-14.3 (R)	Edge of river 1.5 miles downstream of confluence with Saddle River	Bathymetry data indicate section of exposed mudflat habitat	Spotted sandpiper Herring gull Belted kingfisher Muskrat
10	15.6 (R)	Mouth of Saddle River	Possible cove area and associated mudflats that provide cover and spawning habitat to aquatic receptors	Spotted sandpiper Herring gull Belted kingfisher Muskrat Snapping turtle Bullfrog
11	16.5-16.7 (R)	Shoal area downstream of Dundee Dam	Bathymetry data indicate section of exposed mudflat habitat	Spotted sandpiper Herring gull Muskrat

[a] See Figures 4, 5, and 6 for maps depicting mudflat locations.



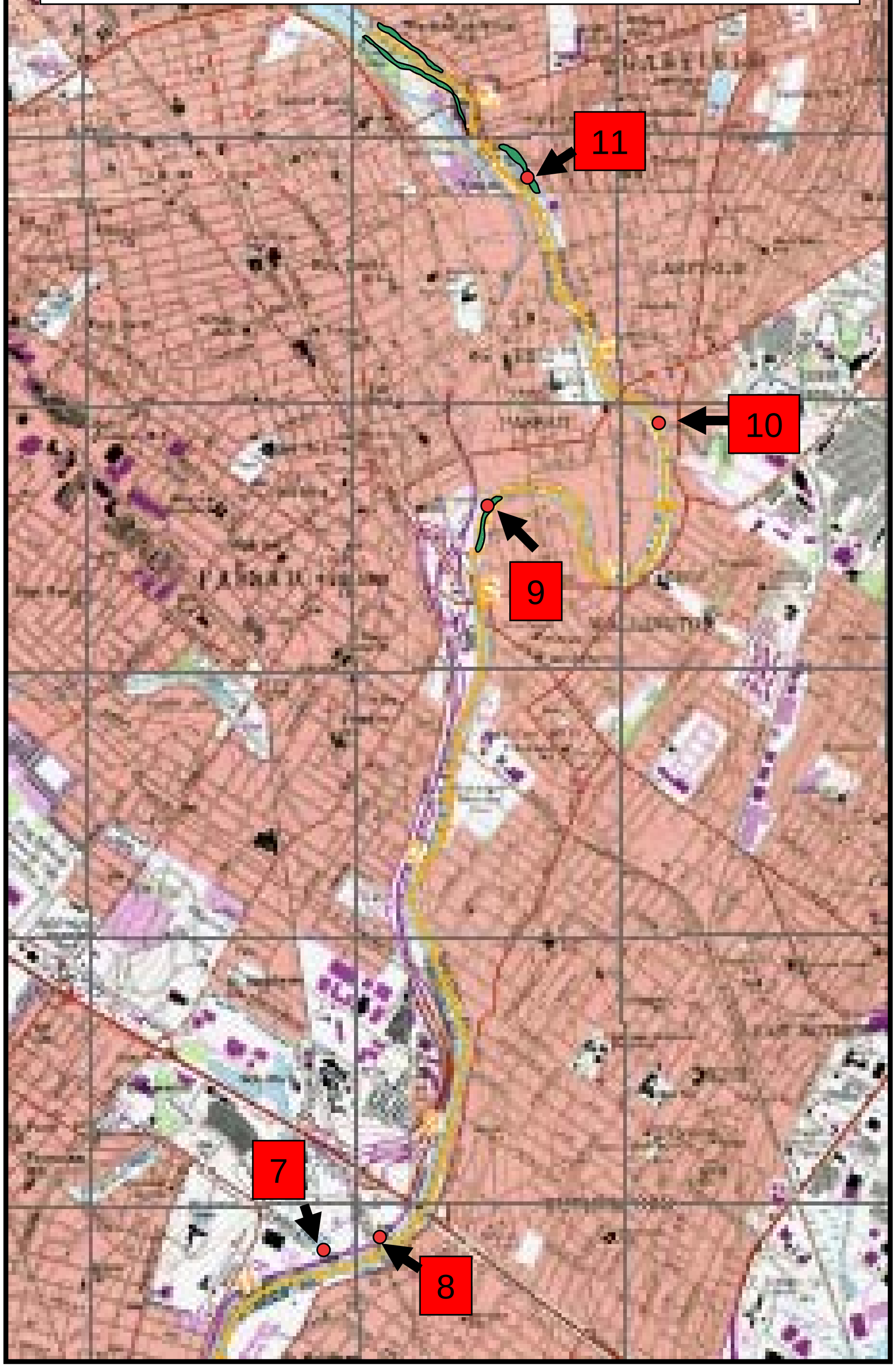
Note: Red boxes depict mudflat habitats along the lower segment of the study area (*Battelle, 2005b*).

Figure 5. Middle Segment of the Study Area



Note: Red boxes depict mudflat habitats along the middle segment of the study area (*Battelle, 2005b*).

Figure 6. Upper Segment of the Study Area



Note: Red boxes depict mudflat habitats along the upper segment of the study area (*Battelle, 2005b*).

III. Refined COPEC Screen

This section presents the proposed approach to define the contaminants of potential ecological concern (COPECs) in the Lower Passaic River. COPECs are chemical contaminants that are identified as presenting potential ecological risk. The approach is a tiered process, involving Steps 1 though 3 of USEPA's *Ecological Risk Assessment Guidance for Superfund* (USEPA, 1997). These steps determine which contaminants can be eliminated from further consideration and which should be evaluated further. The approach presented here is based on available historical data and will be updated for the BERA to include new data from the Passaic River as they become available. Therefore, the COPEC list presented is only an example of the process, is not a final list, and is likely to change for the final BERA. The approach is described in detail below and is illustrated in Figure 7.

1. In the first step of the screening process, data are evaluated to ensure that laboratory detection limits that were specified in the Quality Assurance Project Plan (QAPP) are met. Analytes are selected for further evaluation if they were detected above the laboratory detection limits.

2. Of the detected analytes, any that are considered to be essential nutrients (*e.g.*, calcium, potassium, sodium) are screened out and eliminated from further consideration.

3. The detected analytes that are not essential nutrients are then compared to appropriate screening values that are protective of all possible receptors (*i.e.*, fish, benthic organisms, birds, mammals). If the detected concentration for any analyte is below the screening value, the analyte is screened out from further evaluation. If there is no screening value available and this is the initial screen (*i.e.*, Screening Level Ecological Risk Assessment [SLERA] step), the analyte is retained as a COPEC. If this is not the initial screen (*i.e.*, BERA step) and there is no surrogate screening value available, the analyte is evaluated during the uncertainty analysis of the BERA. If there is a surrogate screening value available, the analyte is evaluated further.

4. If the detected concentration for any analyte is above the screening value, the analyte is evaluated based on its frequency of detection. For instance, if the analyte was detected in less than 5% of the samples, it may be eliminated from further consideration. However, for infrequently detected analytes, an evaluation of the spatial distribution of the data will be conducted to determine whether a potential "hot spot" exists (*i.e.*, there is less than 5% detection, but all samples are located in one area). If a potential "hot spot" is identified, the analyte may be reclassified as a COPEC. If the data are all located within one area, but are correlated with other identified COPECs, the analyte will be eliminated from further consideration.

5. The remaining inorganic analytes are then compared to background or regional sediment concentrations (dataset to be determined). If the concentration of any analyte is below the background or regional concentration, the analyte is eliminated from further analysis.

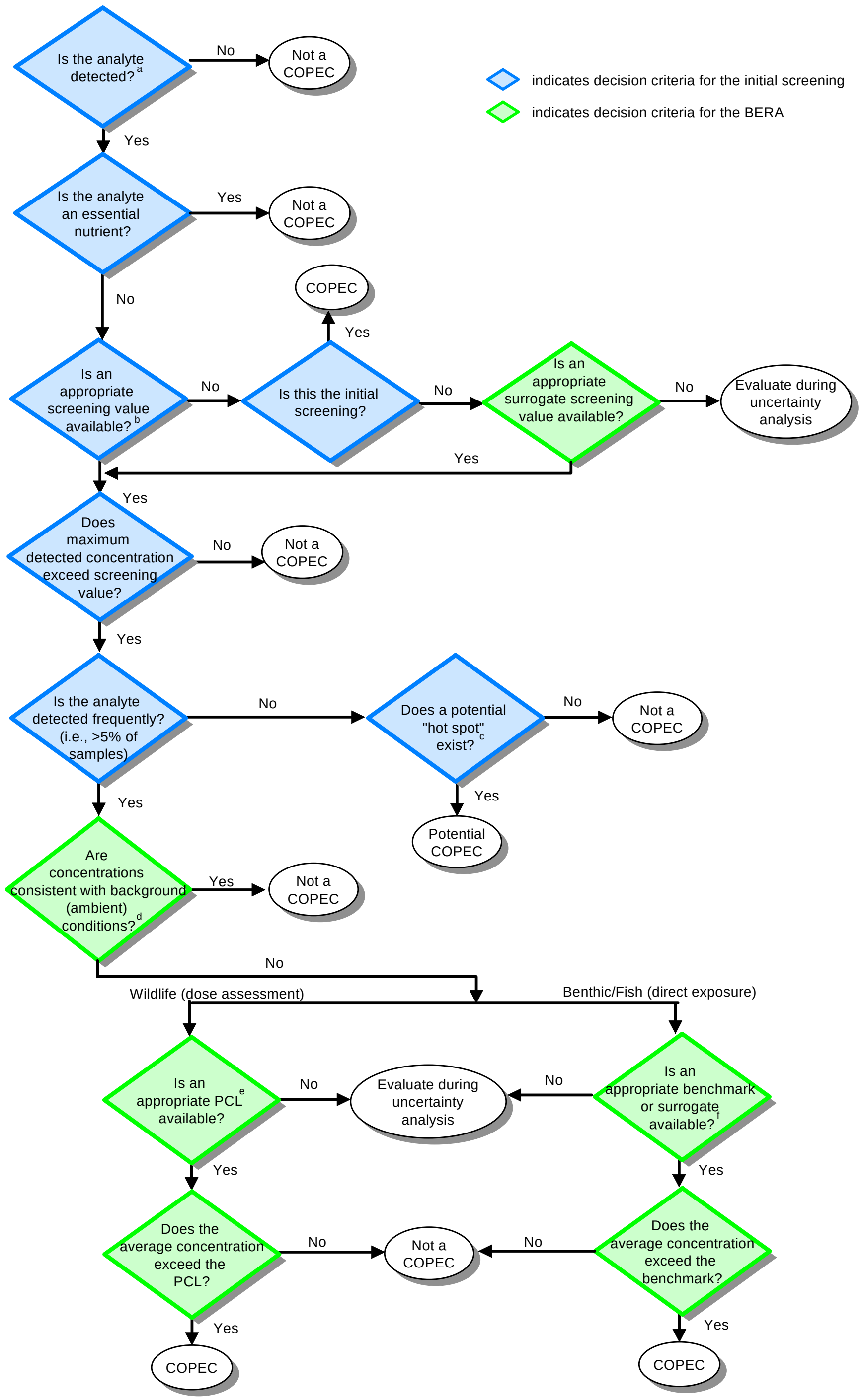
6. The remaining analytes are evaluated against protective concentration levels (PCLs) for terrestrial wildlife, which account for bioaccumulation hazards in upper-trophic level receptors. PCLs will be derived based on realistic assumptions (*e.g.*, receptor-specific foraging frequency, chemical-specific bioavailability). For fish and benthic organisms, sediment quality benchmarks (*e.g.*, effects-range median [ER-M], probable effect levels [PEL]) will be used for evaluation. Any analytes that are below these values are screened out from further consideration; analytes that are above these values are retained as COPECs. If

there are no PCLs or sediment quality benchmarks available for any analyte, the analyte is retained and evaluated during the uncertainty analysis of the BERA.

7. The final set of COPECs will be evaluated in the BERA through exposure and effects using a dose-model.

The initial steps (steps 1 through 4) were performed on the historical sediment dataset for the Lower Passaic River, available at www.ourpassaic.org, and were presented in the PAR (Battelle, 2005a). The list from the initial screen identified a total of 88 COPECs. Further refinement using steps 3 through 6 resulted in 24 COPECs and two potential COPECs. Table 6 presents the COPECs identified from both the initial screen in the PAR and the refinement for the BERA.

Figure 7. Flowchart for Contaminant of Potential Ecological Concern (COPEC) Selection Process



[a] Data will be evaluated to ensure that QAPP-specified detection limits were achieved.

[b] Screening values will be protective of all potential receptors, including wildlife.

[c] For infrequently detected analytes, an evaluation of the spatial distribution of the data will be conducted to determine whether the distribution is correlated with identified COPECs or whether a potential "hot spot" exists. If a potential hot spot is identified or the analytical data are not well correlated with the COPECs, the analyte may be reclassified as a COPEC.

[d] Process to determine "consistency with background conditions" to be determined; applies only to inorganic analytes.

[e] PCL= wildlife protective concentration levels; will be derived based on realistic assumptions appropriate for the BERA (e.g., receptor-specific foraging frequency, chemical specific bioavailability).

[f] BERA screening benchmarks for COPEC selection process will be based on effects–range median (ERM), probable effects levels (PEL), etc.

Table 6. Contaminants of Potential Ecological Concern (COPECs) Identified in Passaic River Surface Sediments

Analyte	Pathways Analysis Report (PAR)[a]		Refined COPEC Selection[b]	
	Lower River	Upper River	Lower River	Upper River
METALS				
Antimony	✔	✔		
Arsenic	✔	✔		
Barium	✔	✔		
Beryllium	✔	✔		
Cadmium	✔	✔		
Chromium	✔	✔		
Cobalt	✔	✔		
Copper	✔	✔	✔	✔
Cyanide	✔			
Iron	✔	✔		
Lead	✔	✔	✔	✔
Manganese	✔			
Mercury	✔	✔	✔	✔
Nickel	✔	✔	✔	✔
Selenium	✔	✔		
Silver	✔	✔	✔	✔
Thallium	✔	✔		
Titanium	✔	✔		
Vanadium	✔	✔		
Zinc	✔	✔	✔	✔
VOCs				
Chlorobenzene		✔		✔
Ethylbenzene	✔		*	
Methyl chloride		✔		
Toluene		✔		
Xylenes, Total	✔		*	
Petroleum Hydrocarbons	✔	✔		
TPH - DRO	✔	✔		
SVOCs				
1,2,4-Trichlorobenzene	✔			
1,2-Dichlorobenzene	✔			
1,3-Dichlorobenzene	✔			
1,4-Dichlorobenzene	✔	✔	✔	✔
Bis(2-Ethylhexyl)phthalate	✔		✔	
Butyl benzyl phthalate	✔		✔	
Carbazole	✔	✔		
Dibenzofuran	✔	✔	✔	✔
Dibenzothiophene	✔	✔		
Dibutyltin	✔	✔		
Di-n-octyl phthalate	✔	✔		
Monobutyltin	✔	✔		

Table 6. Contaminants of Potential Ecological Concern (COPECs) Identified in the Upper and Lower Passaic River Surface Sediments, continued

Analyte	Pathways Analysis Report (PAR)[a]		Refined COPEC Selection[b]	
	Lower River	Upper River	Lower River	Upper River
N-nitroso-di-phenylamine	✔			
Tetrabutyltin	✔			
Tributyltin	✔	✔	✔	✔
PAHs				
1-Methylnaphthalene	✔	✔		
1-Methylphenanthrene	✔	✔		
2-Methylnaphthalene	✔	✔		
2,3,5-Trimethylnaphthalene	✔	✔		
2,6-Dimethylnaphthalene	✔	✔		
Acenaphthene	✔	✔		
Acenaphthylene	✔	✔		
Anthracene	✔	✔		
Benz[a]anthracene	✔	✔		
Benzo[a]pyrene	✔	✔		
Benzo[b]fluoranthene	✔	✔		
Benzo[e]pyrene	✔	✔		
Benzo[g,h,i]perylene	✔	✔		
Benzo[k]fluoranthene	✔	✔		
Chrysene	✔	✔		
Dibenz[a,h]anthracene	✔	✔		
Fluoranthene	✔	✔		
Fluorene	✔	✔		
Indeno[1,2,3-c,d]-pyrene	✔	✔		
Naphthalene	✔	✔		
PAHs, High Molecular Weight (HMW)	✔	✔	✔ [c]	✔ [c]
PAHs, Low Molecular Weight (LMW)	✔	✔	✔ [c]	✔ [c]
PAHs, Total	✔	✔	✔ [c]	✔ [c]
Perylene	✔	✔		
Phenanthrene	✔	✔		
Pyrene	✔	✔		
PCBs				
Total PCBs (Aroclors)	✔	✔	✔	✔
Total PCBs (Congeners)	✔	✔	✔ [d]	✔ [d]
PESTICIDES				
4,4'-DDD	✔	✔		
4,4'-DDE	✔	✔		
4,4'-DDT	✔	✔		
DDTs, Total	✔	✔	✔ [e]	✔ [e]
BHC- alpha	✔			
BHC - beta	✔	✔		
BHC - gamma	✔			

Table 6. Contaminants of Potential Ecological Concern (COPECs) Identified in the Upper and Lower Passaic River Surface Sediments, continued

Analyte	Pathways Analysis Report (PAR)[a]		Refined COPEC Selection[b]	
	Lower River	Upper River	Lower River	Upper River
Aldrin	✔	✔		✔
Chlordane (total)	✔	✔	✔	✔
Dieldrin	✔	✔	✔	✔
Endrin (total)	✔	✔	✔	
Endosulfan (total)	✔	✔	✔	✔
Heptachlor (total)	✔	✔		
Hexachlorobenzene	✔			
Methoxychlor	✔			
2,4,5-TP	✔			
2,4-DB	✔			
DIOXINS/FURANS				
2,3,7,8-Tetrachlorodibenzodioxin (TCDD)	✔	✔	✔ [f]	✔ [f]

[a] COPEC evaluation and selection were performed by Battelle, under contract to Malcolm Pirnie, Inc. for the Pathways Analysis Report (PAR) for the Lower Passaic River Restoration Project (Battelle, 2005a). Surface sediment data were evaluated from the database collected by Malcolm Pirnie, Inc., available at www.ourpassaic.org. This analysis occurred over the entire 17-mile portion of the river, which was divided into two segments: the Lower River (0-6.9 miles) and the Upper River (6.9-17 miles).

[b] Due to the lengthy list of COPECs identified for the 17-mile portion of the Passaic River, the initial list of COPECs from the PAR will be further refined for continued work on the Lower Passaic River Restoration Project. The list presented here is an example of the refined approach. The final list of COPECs will be determined using the final risk assessment database and will include a screening step using Protective Concentration Levels (PCLs) that are protective of bioaccumulation hazards in wildlife receptors.

[c] All PAHs will be analyzed and summed, according to molecular weight, to report the total high molecular weight (HMW) PAHs and total low molecular weight (LMW) PAHs, as well as a sum total PAH value.

[d] Total dioxin-like PCB congeners will be evaluated using the toxic equivalency approach (TEQ), as described by Van den Berg et al., 1998.

[e] Total DDTs will include a summation of all six DDx isomers (4'4- and 2'4-).

[f] Dioxins/furans will be evaluated using the most toxic congener (2,3,7,8-TCDD) and the TEQ approach described by Van den Berg et al., 1998.

Notes:

✔ indicates a COPEC

* indicates a potential COPEC. For those analytes identified as potential COPECs, an evaluation of the spatial distribution of the data will be conducted to determine whether the distribution is correlated with identified COPECs or whether a potential "hot spot" exists. If a potential "hot spot" is identified or if the analytical data are not well correlated with the COPECs, the analyte may be reclassified as a COPEC.

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